TITLE

ELECTRONIC IDENTIFICATION TAG INTERROGATION METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an electronic identification tag interrogation system method in which an

5   electronic tag is attached to a person or object for identification purposes. The present method resolves the problem of collisions between replies from various electronic identification tags received by a sensing portal.

10   ### 2. Description of the Prior Art

Electronic identification tag systems are known for tracking personnel and property. The electronic identification tags track personnel and property as they enter and exit a monitored area through various portals.

15   Such electronic identification tags are also used to

detect unauthorized access by personnel through portals to secured areas.

The tracking of personnel and property is accomplished by monitoring the location of an electronic

.5   identification tag attached to the personnel or property. Interrogation means provided at the portals to a confined area monitor the ingress and egress of personnel and property through each portal. By monitoring the ingress and egress of personnel and property through various

10   portals, the location of the personnel or property in a much larger facility can be determined.

In order to track the personnel or property, a transmitter provided at a portal sends an interrogation message which is received by the electronic identification

15   tags affixed to personnel or property within the search field of the portal. Usually, the search field of a portal is directed to a confined area controlled by the portal. A transmitter provided in the electronic identification tag responds to the interrogation message

20   by sending a reply message. Frequently, the interrogation message from a portal includes a portal identifier which instructs the electronic identification tag to reply with a similar portal identifier included in the reply message. The portal identifier instructs only the proper portal to

25   process the reply, thereby eliminating processing of a

reply message by an unintended portal which is within the transmission range of the electronic identification tag. Thus, if two portals receive a reply signal from an electronic identification tag, the reply message includes

5   means for determining which portal should process the reply message.

Where the number of personnel or packages being tracked is large, the possibility exists that a number of reply messages from the electronic identification tags

10   affixed to the personnel or packages will collide when received by the portal. To minimize problems caused by colliding reply signals, prior art interrogation systems provide a time variant delay in the electronic identification tag responses. This time variant delay is

15   at least pseudo-random to provide diversification of responses and minimize collisions of the reply messages.

The prior art time variant delay diversification scheme is proposed for the situation in which two tags are in the field of an interrogating portal and reply at

20   exactly the same time. This is usually not a problem for access portals where a tag is used to unlock a gate or activate an escapement to allow entrance to an area. The tag in this case is activated by a portal field that is limited in range of activation. Otherwise, a tag in back

25   of the first can open the lock by a process known as

"tailgating". Physical means are needed to limit the "tailgating" to guarantee that consecutive tags are not mistaken for each other. This is accomplished by shaping the interrogating field of influence at a portal. In such

5   an instance, a time variant delay diversification scheme to prevent collisions of reply messages may not be necessary.

A different type of portal reading device is necessary for loading parcels or bags, such as of mail,

10   onto trucks. In this case, a portal reading device located at the top of the truck opening records the loading or unloading of parcels. The portal reading device consists of two interrogation heads which indicate that the parcel has been moved from an area just outside

15   the truck opening onto the truck bed. The use of two interrogation heads provides the ability to determine that the parcel or bag was actually loaded onto the truck bed. Because of the proximity of the two interrogation heads, there is a possibility that the fields of the separate

20   heads may overlap. To overcome this problem, the overlap area may be fashioned to become a region of ineffective communication and, therefore, a dead zone. A microprocessor receives input from the interrogation heads and monitors whether the parcels have been loaded onto the

25   truck beds. During interrogation, the replies from the

electronic identification tags may collide.

Diversification of the replies is necessary to prevent the

continuation of the collisions.

5   As stated previously, the prior art employs a

time delay system to achieve diversification of replies.

A problem arises with such a diversification scheme when a

large volume of parcels may possibly be expected to be

present within the field of the interrogation heads. In

order to accommodate a large volume of parcels, an equal

10   number of diverse time delays must be provided.

Consequently, every time an interrogation signal is

transmitted, the monitoring system must wait for every

possible time delayed response to arrive before

retransmitting an interrogation signal. If the

15   interrogation system is provided with 100 time delays, the

transmitter must wait for all 100 diverse time-delayed

responses to be sent before retransmitting an

interrogation signal. The system must wait for reception

of all possible time-delayed response signals regardless

20   of the actual volume of parcels present in the

interrogation field. In other words, when time delay

diversification is used, the interrogation system must

wait for the possibility of every conceivable reply

regardless of whether or not a parcel is present to

25   provide such a reply. Consequently, there is a need for

an interrogation system which eliminates the frequently
unnecessary wait for the last conceivable time-delayed
reply.

SUMMARY OF THE INVENTION

5   An electronic identification tag interrogation
system is provided in which a portal is provided with
transmitter means for providing an RF interrogation signal
and receiving means for responding to an RF tag signal
having identifying data encoded therein. At least one
10 electronic identification tag is provided having supply
means for providing electrical power to the tag. The tag
is also provided with an address and with memory means for
storing identifying data associated with the tag. The tag
includes both an RF receiver means powered by the supply
15 means for processing an interrogation signal and RF
transmitter means for transmitting identifying data stored
in the memory means in response to the receipt by the RF
receiver means of an interrogation signal having a request
encoded therein. The electronic identification tag is
20 also provided with means for suppressing the RF
transmitter means in response to a signal requesting the
tag to suppress further responses.

In operation, the portal transmits an
interrogation signal requesting a response from all
electronic identification tags having an address field
greater than a given value usually "0 state". If no
5   responses are received, the interrogation is complete. If
only one response is received, the portal can address that
electronic identification tag directly. If more than one
response is received by the portal, the interrogation
system will employ a series of address field bisection
10   steps in order to isolate a single response. When such a
single response is received, the portal communicates
directly with the isolated electronic identification tag
and then transmits a signal to the identification tag to
suppress any further responses. The interrogation system
15   is then reset to continue interrogation until each
identification tag is isolated and acknowledged.

BRIEF DESCRIPTION OF THE DRAWING

20   ~~The~~ Figure 1 is a block diagram of a presently
preferred embodiment of the electronic identification tag
interrogation system of the present invention. '

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention uses a diversification scheme that assigns a different tag identification number to each of the electronic identification tags 28 that are expected to reply to an interrogation. The interrogator 26 sends a request for all tags 28 to look at their identification numbers, and, if the tag identification number is greater than the requested address from the interrogator 26, the tag replies. Under conditions of tag 28 collisions, the interrogator 26 conducts a direct search on tag identification numbers using bisection until a single tag 28 responds. The interrogator 26 acknowledges each of the replies which are not garbled, transmits a suppression signal to the identified tag 28 and sends the next interrogation message.

The interrogation method can be best understood with reference to Figures 1 through 4 ~~the block diagram of the Figure~~. The block diagram of Figure 1 ~~the Figure~~ represents a direct search interrogation method for a tag identification range from 1 to $2^m - 1$ tags. Each tag 28 is encoded with a different identification number. A tag 28 is instructed to reply to an interrogation signal if the tag identification number is greater than or equal to A (the interrogation address).

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When the direct search interrogation method

starts, index j is set at 0 in step 10. The interrogation

address A is also set at 0 in step 12. Provided index j

is less than or equal to m, the index j is incremented one

5   unit in step 14 and the interrogation is conducted in step

16.

     If the portal interrogator receives only one

reply, the responding tag is acknowledged in step 18 and

the direct search interrogation method is reset to the

10   start, step 10. Once an identification tag is

acknowledged, the portal interrogator instructs that tag

not to respond to further interrogations from the same

portal number. This reply suppression will be reset by

the portal after all identification tags are acknowledged.

15   If the portal interrogation receives more than

one reply, the interrogation address is incremented by

$2^{(m-j)}$, in step 20. Provided index j is less than or

equal to m, the index j is again incremented by 1 in step

14 and the interrogation signal is retransmitted in step

20   16. In the event that index j is greater than m, the

direct search interrogation method is reset to start, step

10. This bisection process is continued until the portal

interrogation receives only a single reply.

     If, after an interrogation, the portal

25   interrogator does not receive any replies, the

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interrogation address A is changed from A to $A-2^{(m-j)}$ in

step 22. If A is less than or equal to 0, the direct

search interrogation method is returned to the start, in

step 10. If the interrogation address A is greater than

5   0, the index j is incremented by 1 in step 14 and

interrogation is again conducted in step 16 provided index

j is less than or equal to m.

For 32 bit-tag identification numbers, the

bisection process may require as many as 33 separate

10 interrogations per tag. However, the number of

interrogations may be decreased by providing additional

diversity to the direct search system. Additional

diversity may be achieved by permitting more than one tag

to respond per interrogation for any given address number

15 by means of discrete time slots. The time slots can be

picked from the least significant bits of the tag

identification number. For example, 8 discrete time slots

can be obtained by allocating three bits of the tag

identification number to provide the time delayed

20 responses. By using the additional diversity of three

bits, the search field is reduced from 32 bits to 29 bits.

With this additional diversity, a maximum of 30

interrogations are needed to resolve a conflict of two

tags responding in exactly the same time slot.

In a typical interrogation system, the
interrogation message is sent at 9600 baud and requires 43
bits of information. This message takes approximately 5
milliseconds to transmit. Each electronic identification

5 tag replies with 63 bits of information at 100 kbaud,
taking less than 700 microseconds. The 8 time-delayed
replies thus take approximately 5 milliseconds. Since the
interrogation signal and reply signal are sent at vastly
different frequencies in the low RF and UHF bands

10 respectively, full-duplex operation can be obtained. The
replies can keep up, therefore, with the interrogations,
although processing time may provide another limitation.
For electronic identification tags responding in exactly
the same time slot, the direct search is imposed until

15 uniquely one reply is obtained. For two electronic
identification tags replying in the same time slot, thirty
interrogations (150 milliseconds) may be required in the
worst case to find both tags. The acknowledgements from
the interrogator are directed messages and require an

20 additional 5 milliseconds for each acknowledgement, giving
a worst case total of 155 milliseconds for the
interrogation.

It is expected that a large number of tags may
suddenly appear at a portal at any given time. Assuming

25 that the tag addresses are established to interfere with

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the above scheme in the worst possible situation, an

absolute worst case time to interrogate and sort the tags

can be determined. The worst-case time to interrogate and

sort N tags is given by the equation [(N-1)(150 ms) + 5

ms]. For a 100-tag pile, this absolute worst-case time to

interrogate and sort the 100 tags is 14.9 seconds. On the

average, this worst-case time will be one-eighth the

length because of the eight-fold time-slot diversity made

possible by the hybrid direct search and time diversity

scheme.   Additionally, another factor of 2 can be claimed

for where the tag numbers are in the range of 2^{32}, which

is the range of the tag numbers. In addition,

modifications may be made to the search algorithm to

achieve additional reductions. Such additional time

reductions may arise because it is not always necessary to

return to the beginning of the search each time a unique

tag is identified.

    The tag reply message should be kept portal-

specific for ungarbled messages in order to eliminate the

possibility of reception of the reply message by more than

one portal. For garbled messages where tag replies from

more than one portal are involved, the direct search

method resolves the conflict. Because the tag

identification numbers are distinct, the search algorithm

at each portal still sorts between the repliers by

discrete interrogations. In such a manner, a portal-
specific reply for an ungarbled message is received.

In a preferred embodiment of the invention, the
reply suppression of an identification tag is accompanied
by a shift in the power consumption level of the
identification tag to a lower power mode. In this lower
power mode, which conserves the battery power supplying
the identification tag, the identification tag does not
listen to instructions or other communications transmitted
by a portal. Instead, the identification tag periodically
energizes for the limited purpose of detecting a loss of
carrier. A loss of carrier may occur when either the
identification tag is removed from the field of a portal
interrogator or when the portal interrogator is turned
off. Once the identification tag detects a loss of
carrier, it will continue to periodically energize for the
limited purpose of detecting the presence of a carrier.
If a carrier is detected, the identification tag is turned
on and will listen for communications from the portal
interrogator.

In this preferred power saving embodiment, the
identification tag consumes less power because the decoder
circuitry is turned off during the entire lower power
mode. In addition, the periodic operation of the
identification tag receiver also serves to conserve power.

However, if power consumption is not a concern, the

receiver and decoder circuitry of the identification tag

may be maintained in an active mode at all times. In this

case, the portal interrogator can manually send

5   instructions to the identification tag to disable and re-

enable the acknowledgement replies of the identification

tag.

In the foregoing specification certain preferred

practices and embodiments of this invention have been set

10 out, however, it will be understood that the invention may

be otherwise embodied within the scope of the following

claims.